4.0 TMDL METHODOLOGY AND CALCULATION

4.1 Methodology

This section discusses the methodology used for TMDL development and results in terms of TMDLs and required load reductions for the stream segments listed on Pennsylvania's and Delaware's 303(d) lists as impaired due to nutrients and low DO (see Figures 4-1 and 4-2).

To determine nutrient TMDLs for the Christina River Basin listed waters, three models were used: the HSPF watershed loading model, the XP-SWMM CSO discharge model, and the EFDC receiving water model. The HSPF and EFDC models were calibrated using the four-year period October 1, 1994 to October 1, 1998. All three models were run using this same four-year simulation period to calculate the baseline and allocation loads. The HSPF model was used to estimate nonpoint source loads from 70 subbasins in the Christina River Basin. The nonpoint source loads were then input to the EFDC receiving water model for more detailed analysis of instream water quality conditions. The HSPF model was also used to calculate nutrient loads at the Pennsylvania-Delaware state line since the Delaware WQS applies to Pennsylvania at their common border. The calculation at the state line affected four streams: Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run in the Red Clay Creek watershed. In addition, the HSPF model was used to calculate nutrient loads for several smaller listed stream segments that were not included in the EFDC model. The XP-SWMM model was used to calculate nutrient loads from the CSO discharge points in the City of Wilmington. The daily time-series loads from the HSPF model and from the XP-SWMM model were then input to the EFDC receiving water model to simulate nutrient concentrations in the tidal waters of the Christina River and Brandywine Creek.

Baseline conditions for the TMDL included meteorology and hydrology for the October 1, 1994, to October 1, 1998, calibration period. NPDES flows were set to their permit limits for the entire four-year simulation period. Pennsylvania NPDES facilities operated with seasonal permit concentrations for CBOD, ammonia nitrogen, and total phosphorus. During the winter periods from November 1 to April 30, the concentration of 5-day CBOD (CBOD5) was set to two times the summer concentration and ammonia-nitrogen concentration was set to three times the summer value. During the period November 1 to March 31, the total phosphorus concentrations for each Pennsylvania NPDES facility were set to twice of the summer permit concentration. CSO loads from the City of Wilmington were estimated using simulated flow rates from the XP-SWMM model and event mean concentrations from a storm-water monitoring program. Septic loads and land use coverage from 1995 were used for the baseline conditions in the HSPF watershed model.

4.2 TMDL Calculation

TMDLs were established for each individual stream segment listed for nutrients on the Pennsylvania and Delaware Section 303(d) lists. Each TMDL consists of a point source waste load allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). These TMDLs identify the sources of pollutants that cause or contribute to the impairment and allocate appropriate loadings to the various sources. The basic equation used for TMDLs and allocations to sources is:

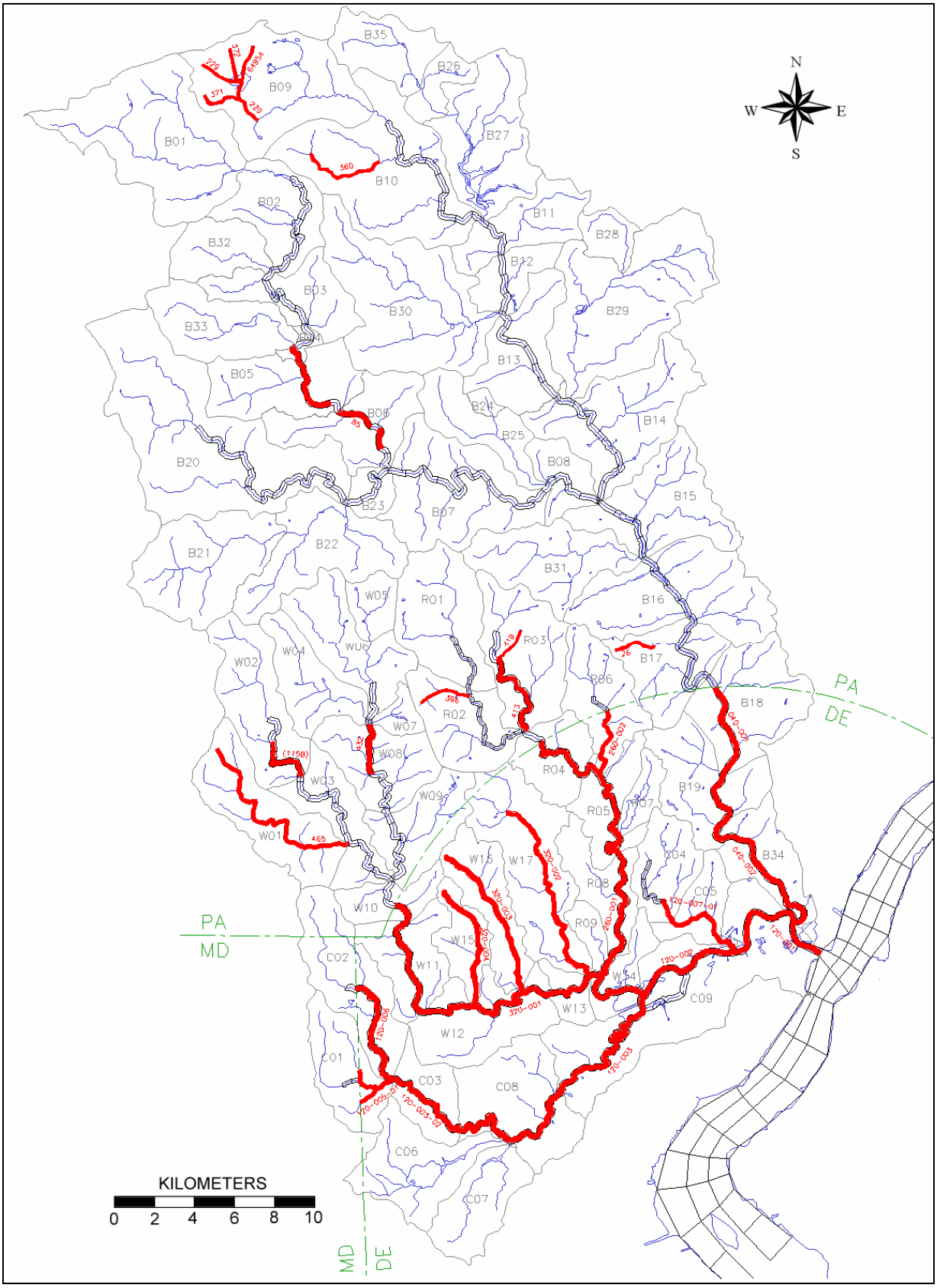

Figure 4-1. Stream segments impaired by nutrients and low DO on 1996 303(d) lists

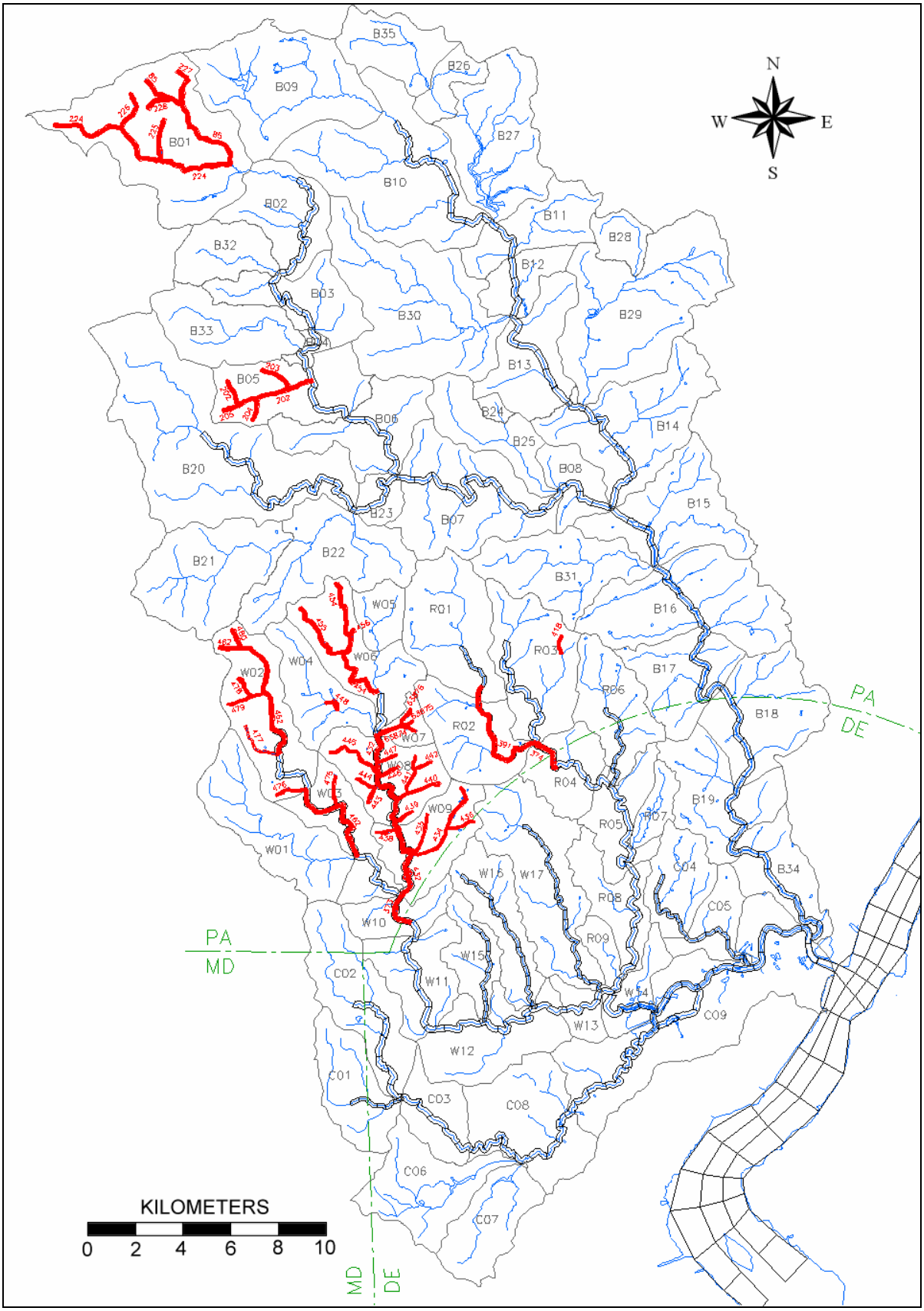

Figure 4-2. Stream segments impaired by nutrients and low DO on 1998 303(d) lists

$$\mathbf{TMDL = \sum WLAs + \sum LAs + MOS}$$

The WLA portion of this equation is the total loading assigned to point sources. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit five percent of MOS was used for this TMDL.

4.3 Waste Load Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source. Based on the water quality model simulations, none of the non-MS4 NPDES permitted dischargers in the impaired subbasins were required to reduce their present NPDES permit limits for CBOD, nitrogen, or phosphorus.

The wasteload allocation (WLA) portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. EPA's stormwater permitting regulations require municipalities to obtain permit coverage for all stormwater discharges from municipal separate storm sewer systems (MS4). On November 22, 2002, an EPA Memorandum from Robert Wayland and James Hanlon, Water Division Directors (see Appendix B) clarified existing regulatory requirements for MS4s connected with TMDLs). The key points are:

- NPDES-regulated MS4 discharges must be included in the wasteload allocation component of the TMDL and may not be addressed by the load allocation component of TMDL
- The stormwater allotment can be a gross allotment and does not need to be apportioned to specific outfalls
- Industrial storm water permits need to reflect technology-based and water quality-based requirements

Based on this memorandum, MS4s within the Christina River watershed are treated as point sources for TMDL and NPDES permitting purposes, and the nutrient loading generated within the boundary of an MS4 area was assigned a WLA. Each of the townships/municipalities within the watershed has been designated by PADEP as needing coverage under NPDES Phase II Stormwater Regulations, and comprises almost the entire watershed area. To determine the nutrient loading associated with each MS4, the township boundary GIS layer was overlaid with the land-use coverage. Nutrient loadings were estimated based on drainage areas of each municipality, and the area-weighted WLAs were further allocated by the land use distribution of each municipality (see Appendix C).

At this time, EPA cannot determine what portion of the municipalities are designated/used for collection or conveying stormwater, as opposed to portions that are truly nonpoint sources. As part of the Phase II process, MS4s will be responsible for evaluating and mapping out areas that are contributing to or collected in storm sewers. Since these systems have not yet been delineated, the TMDL includes nonpoint source loadings into the WLA portion of the TMDL. Once these delineations are available, the nonpoint source loadings can then be separated out of the WLAs and moved under the LA. Until that time, the WLAs have been broken down by land

uses. These areas should not be precluded from nonpoint source funding, such as Growing Greener and Section 319 grants.

4.4 Load Allocations

According to federal regulations (40 CFR 130.2(g)), load allocations are best estimates of the nonpoint source or background loading. These allocations may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading.

As explained in Section 4.1.3, once a municipality delineates its MS4 area, the nutrient loads associated with nonpoint sources may be parsed out of the WLA and moved under the LA portion of the TMDL. Note that the total allocation will be unchanged.

4.5 TMDL Results and Allocations

The impaired stream segments on the 303(d) list for nutrients and low DO in the Pennsylvania portion of the Christina River Basin are located in the Brandywine Creek, White Clay Creek, and Red Clay Creek watersheds. The HSPF and EFDC models for were run for the period October 1, 1994, to October 1, 1998, for both the baseline (current) conditions and for the TMDL allocation conditions. The WLA from the low-flow TMDL (USEPA, 2002) was used as the baseline conditions for the NPDES facilities in this high-flow TMDL. Watershed loads of nutrients were adjusted in the TMDL allocation scenarios until the target endpoints described in Section 3.0 were achieved. The allocation process included the following steps.

(1) For the impaired Pennsylvania subbasins, the nutrient loads were reduced as necessary to protect the DO water quality standards.
(2) At the Delaware-Pennsylvania state line, the simulated TN and TP concentrations were used to determine the Pennsylvania allocations for TN and TP necessary to achieve Delaware's guidance of 3.0 mg/L and 0.2 mg/L, respectively.
(3) At the Maryland-Delaware state line, the simulated TN and TP concentrations were used to calculate the Maryland allocations for TN and TP necessary to achieve Delaware's guidance of 3.0 mg/L and 0.2 mg/L, respectively.
(4) For the upper Delaware subbasins, the TN and TP guidance concentrations were used to adjust nutrient loads, as necessary, in each subbasin. Also, protection of the WQS for DO, nitrate-nitrogen, and ammonia-nitrogen was determined and additional load reductions were made, as necessary, to achieve the WQS.
(5) For the tidal Christina River near the mouth of the basin, the model was run with reductions stipulated in steps (1) to (3) above and the TMDL endpoints pertaining to Delaware (see Table 3-1) were evaluated to determine if reductions were necessary to CSO loads from the City of Wilmington.

4.5.1 Pennsylvania Allocations at PA-DE State Line

Water flowing into Delaware from Pennsylvania must meet Delaware WQS at the Delaware state line. There are four streams that enter Delaware from Pennsylvania: Brandywine Creek, White Clay Creek, Red Clay Creek, and Burroughs Run. The results from the linked HSPF-EFDC models for these four streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state

line. The preliminary Pennsylvania allocations for nutrients at the state line are shown in Table 4-1. The baseline and allocation loads in Table 4-1 represent the average nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve an average endpoint concentration over that same period. Model results indicate the load reductions from baseline conditions range from about 0% to 46% for total nitrogen, and from 0% to 72% for total phosphorus.

Table 4-1. Total nitrogen and total phosphorus allocations at PA-DE state line

Location	Baseline Load (kg/day)	Pennsylvania Allocation (kg/day)	Reduction
Total Nitrogen			
Brandywine Creek (at PA-DE Line)	6849.8	3663.8	46.5%
White Clay Creek (at PA-DE Line)	956.2	685.0	28.4%
Red Clay Creek (at PA-DE Line)	466.7	320.4	31.3%
Burroughs Run (at PA-DE Line)	43.4	43.4	0.0%
Total Phosphorus			
Brandywine Creek (at PA-DE Line)	423.8	250.8	40.8%
White Clay Creek (at PA-DE Line)	110.6	65.9	40.4%
Red Clay Creek (at PA-DE Line)	62.8	17.2	72.6%
Burroughs Run (at PA-DE Line)	0.8	0.8	0.0%

4.5.2 Maryland Allocations at MD-DE State Line

Water flowing into Delaware from Maryland must meet Delaware WQS at the Delaware state line. There are two streams that enter Delaware from Maryland: the upper Christina River and Christina River West Branch. The results from the linked HSPF-EFDC models for these two streams were used to determine whether the Delaware guideline endpoints for total nitrogen (3.0 mg/L) and total phosphorus (0.2 mg/L) were satisfied at the state line. The TMDL endpoints at the MD-DE state line for the upper Christina River were achieved under baseline conditions. Therefore, no load reductions were necessary to the portion of the watershed feeding the upper Christina River. The preliminary Maryland allocations for nutrients at the Delaware state line for the Christina River West Branch are shown in Table 4-2. The baseline and allocation loads in Table 4-2 represent the average daily nitrogen and phosphorus loads over the four-year model simulation period (October 1, 1994 to October 1, 1998) necessary to achieve the endpoint concentration over that same period. The model simulations indicate the load reductions from baseline conditions were 61.9% for total nitrogen, and 47.5% for total phosphorus.

Table 4-2. Total nitrogen and total phosphorus allocations at MD-DE state line

Location	Baseline Load (kg/day)	Maryland Allocation (kg/day)	Reduction
Total Nitrogen			
Christina River West Branch (MD-DE Line)	68.7	26.2	61.9%
Total Phosphorus			
Christina River West Branch (MD-DE Line)	3.8	2.0	47.5%

4.5.3 Nitrate-Nitrogen and Ammonia-Nitrogen Allocations

Under baseline conditions, the model indicated that the daily average nitrate concentrations were less than 10 mg/L at all grid cell locations within the listed impaired water segments. Therefore, no reductions in nitrogen loads were necessary to achieve compliance with the nitrate-nitrogen WQS of 10 mg/L. Ammonia-nitrogen, which is based on pH and temperature, was investigated during the low-flow study (USEPA, 2002) and it was determined that the ammonia-nitrogen standard was protected throughout the Christina River Basin. Since the critical period for potential violations of the ammonia-nitrogen standard occur during low-flow summer months, no additional investigation was deemed necessary for this high-flow study.

4.5.4 Nitrogen and Phosphorus Allocations

In Pennsylvania, it was necessary to reduce nitrogen and phosphorus loads from both point and nonpoint sources in a number of subbasins in order to protect the minimum and daily average DO water quality standards. The models were run in an iterative fashion to determine the load reductions required from point and nonpoint sources to protect the DO criteria. The load allocations and WLAs are summarized by impaired subbasin in Tables 4-3 to 4-8 below. An explicit 5% margin of safety (MOS) is included in the TMDL allocation. The baseline and preliminary TMDL allocation loads shown in Table 4-3 to 4-8 represent the average daily loads calculated from the HSPF and EFDC model simulations covering the period October 1, 1994, to October 1, 1998. The model results for the baseline condition and TMDL allocations are presented in the graphs in Appendix D. These graphs represent transects along the impaired stream segments included in the water quality model and show the model results in relation to the TMDL target endpoints.

4.5.5 Dissolved Oxygen Allocations

Under the low-flow study (USEPA, 2002), an analysis was performed to investigate potential dissolved oxygen WQS violations during critical conditions. For this scenario, the NPDES point source discharges were set to their maximum permitted flows and concentrations and the model was run under 7Q10 (minimum 7-day flow expected to occur every 10 years) stream flow conditions. Nonpoint source pollutant loads, as computed by multiple data sets, were developed to represent expected conditions and pollutant contributions during critical periods. As a result of the low-flow study, WLAs were recommended for several NPDES discharges on East Branch Brandywine Creek, West Branch Brandywine Creek, West Branch Red Clay Creek, West Branch Christina River to protect the dissolved oxygen WQS. For the baseline conditions of this high-flow TMDL, the NPDES discharges in the Christina River Basin were set to the recommended WLA values from the low-flow study during the summer season. During the winter season, the permitted concentrations of ammonia nitrogen, total phosphorus, and CBOD were increased as described in Section 4.1. The model results for the high-flow TMDL allocations presented in Tables 4-1 to 4-8, indicate that no additional reductions to the non-MS4 NPDES discharges over and above those recommended in the low-flow TMDL are necessary to protect the dissolved oxygen WQS. However, nonpoint source, including MS4s, and CSO load reductions were necessary to achieve the TMDL targets related to dissolved oxygen, total nitrogen, and total phosphorus.

Table 4-3. TMDL summary for Brandywine Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Total	WLA	MS4 WLA	MOS	TMDL	
Total Nitrogen								
B01	31.559	362.174	393.733	31.559	206.439	10.865	248.863	36.8%
B02	0.000	114.369	114.369	0.000	65.191	3.431	68.622	40.0%
B03	2.167	89.226	91.393	2.167	76.289	4.015	82.471	9.8%
B04	0.000	5.369	5.369	0.000	5.101	0.268	5.369	0.0%
B05	558.690	77.512	636.202	558.690	44.182	2.325	605.197	4.9%
B06	0.156	123.362	123.518	0.156	82.035	4.318	86.509	30.0%
B09	0.078	252.455	252.533	0.078	196.663	10.351	207.092	18.0%
B10	3.721	252.455	256.176	3.721	196.663	10.351	210.735	17.7%
B17	1.013	83.890	84.903	1.013	74.117	3.901	79.031	6.9%
B32	0.000	29.001	29.001	0.000	24.796	1.305	26.101	10.0%
B33	1.799	95.092	96.891	1.799	81.304	4.279	87.382	9.8%
Total Phosphorus								
B01	6.360	6.920	13.280	6.360	3.944	0.208	10.512	20.8%
B02	0.000	2.185	2.185	0.000	1.245	0.066	1.311	40.0%
B03	0.540	16.229	16.769	0.540	13.876	0.730	15.146	9.7%
B04	0.000	0.988	0.988	0.000	0.939	0.049	0.988	0.0%
B05	35.524	14.615	50.139	35.524	8.331	0.438	44.293	11.7%
B06	0.040	25.254	25.294	0.040	16.794	0.884	17.718	30.0%
B09	0.020	3.849	3.869	0.020	2.998	0.158	3.176	17.9%
B10	0.429	3.848	4.277	0.429	2.998	0.158	3.585	16.2%
B17	0.221	7.508	7.729	0.221	6.633	0.349	7.203	6.8%
B32	0.000	2.147	2.147	0.000	1.836	0.097	1.933	10.0%
B33	0.115	1.729	1.844	0.115	1.479	0.078	1.672	9.3%

Table 4-4. WLA summary for Brandywine Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads				WLA				Percent Reduction	
			TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN	TP
B01	PA0057339	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
B02	PA0036412	0.0550	10.00	1.90	2.082	0.396	10.00	1.90	2.082	0.396	0.0%	0.0%
B02	PA0044776	0.6000	10.00	1.80	22.715	4.089	10.00	1.80	22.715	4.089	0.0%	0.0%
B03	PA0052728	0.0004	40.00	10.00	0.061	0.015	40.00	10.00	0.061	0.015	0.0%	0.0%
B03	PA0055697	0.0490	10.00	2.00	1.855	0.371	10.00	2.00	1.855	0.371	0.0%	0.0%
B05	PA0011568-001	0.6400	5.30	0.30	12.842	0.727	5.30	0.30	12.842	0.727	0.0%	0.0%
B05	PA0011568-016	0.5045	12.00	0.30	22.919	0.573	12.00	0.30	22.919	0.573	0.0%	0.0%
B05	PA0026859	3.8500	30.00	1.43	437.264	20.857	30.00	1.43	437.264	20.857	0.0%	0.0%
B05	PA0036897	0.3900	30.00	2.00	44.294	2.953	30.00	2.00	44.294	2.953	0.0%	0.0%
B06	PA0053228	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
B06	PA0053236	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
B09	PA0054691	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
B10	PA0050547	0.0375	10.00	1.00	1.420	0.142	10.00	1.00	1.420	0.142	0.0%	0.0%
B10	PA0055492	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
B17	PA0053082	0.0206	10.00	2.00	0.780	0.156	10.00	2.00	0.780	0.156	0.0%	0.0%
B33	PA0012416	0.1400	0.24	0.10	0.127	0.053	0.24	0.10	0.127	0.053	0.0%	0.0%
B33	PA0052990	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
B33	PA0056073	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%

Table 4-5. TMDL summary for Red Clay Creek Watershed

Subbasin	Baseline (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Baseline	WLA	MS4 WLA	MOS	TMDL	
Total Nitrogen								
R01	7.230	126.926	134.156	7.230	60.290	3.173	70.693	47.3%
R02	49.825	104.678	154.503	49.825	49.722	2.617	102.164	33.9%
R03	6.807	120.151	126.958	6.807	57.071	3.004	66.882	47.3%
R04	24.873	39.984	64.857	24.873	18.992	1.000	44.865	30.8%
R05	0.568	34.713	35.281	0.568	16.489	0.868	17.925	49.2%
R06	4.053	67.015	71.068	4.053	63.664	3.351	71.068	0.0%
R07	0.000	3.012	3.012	0.000	2.861	0.151	3.012	0.0%
R08	0.000	23.882	23.882	0.000	22.688	1.194	23.882	0.0%
R09	0.000	7.346	7.346	0.000	6.979	0.367	7.346	0.0%
Total Phosphorus								
R01	0.914	2.277	3.191	0.914	1.082	0.057	2.053	35.7%
R02	7.506	45.473	52.979	7.506	4.320	0.227	12.053	77.2%
R03	1.606	2.845	4.451	1.606	1.352	0.071	3.029	31.9%
R04	1.699	6.407	8.106	1.699	1.887	0.099	3.685	54.5%
R05	0.114	4.249	4.363	0.114	4.037	0.212	4.363	0.0%
R06	0.153	1.269	1.422	0.153	1.206	0.063	1.422	0.0%
R07	0.000	0.424	0.424	0.000	0.403	0.021	0.424	0.0%
R08	0.000	1.383	1.383	0.000	1.314	0.069	1.383	0.0%
R09	0.000	0.360	0.360	0.000	0.342	0.018	0.360	0.0%

Table 4-6. WLA summary for Red Clay Creek Watershed

Subbasin	NPDES	Flow mgd	Baseline Point Source Loads				WLA				Percent Reduction	
			TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN	TP
R01	PA0057720-001	0.0720	10.00	1.90	2.726	0.518	10.00	1.90	2.726	0.518	0.0%	0.0%
R01	PA0057720-002	0.0900	0.24	0.10	0.082	0.034	0.24	0.10	0.082	0.034	0.0%	0.0%
R02	PA0024058	1.1000	10.00	1.27	41.644	5.305	10.00	1.27	41.644	5.305	0.0%	0.0%
R03	PA0055107	0.1500	10.00	2.00	5.679	1.136	10.00	2.00	5.679	1.136	0.0%	0.0%
R04	DE0000451	2.1700	0.24	0.20	1.972	1.643	0.24	0.20	1.972	1.643	0.0%	0.0%
R04	DE0050067	0.0015	40.00	10.00	0.227	0.057	40.00	10.00	0.227	0.057	0.0%	0.0%
R05	DE0021709	0.0150	10.00	2.00	0.568	0.114	10.00	2.00	0.568	0.114	0.0%	0.0%
R06	PA0055425	0.0005	40.00	10.00	0.076	0.019	40.00	10.00	0.076	0.019	0.0%	0.0%
R08	DE0000230	0.3500	0.24	0.10	0.318	0.133	0.24	0.10	0.318	0.133	0.0%	0.0%

Table 4-7. TMDL summary for White Clay Creek Watershed

Subbasin	Baseline Loads (kg/day)			Allocations (kg/day)				Percent Reduction
	PS	NPS	Baseline	WLA	MS4 WLA	MOS	TMDL	
Total Nitrogen								
W01	0.981	157.038	158.019	0.981	74.593	3.926	79.500	49.7%
W02	15.503	133.766	149.269	15.503	57.184	3.010	75.697	49.3%
W03	0.000	87.269	87.269	0.000	41.453	2.182	43.635	50.0%
W04	0.000	83.361	83.361	0.000	39.597	2.084	41.681	50.0%
W06	59.718	168.665	228.383	59.718	80.116	4.217	144.051	36.9%
W07	8.868	29.463	38.331	8.868	13.994	0.737	23.599	38.4%
W08	1.164	129.466	130.630	1.164	61.496	3.237	65.897	49.6%
W09	0.113	79.504	79.617	0.113	37.764	1.988	39.865	49.9%
W10	0.000	32.949	32.949	0.000	15.651	0.824	16.475	50.0%
W11	0.000	39.714	39.714	0.000	37.728	1.986	39.714	0.0%
W12	0.341	52.612	52.953	0.341	49.981	2.631	52.953	0.0%
W13	0.000	12.866	12.866	0.000	12.223	0.643	12.866	0.0%
W14	0.000	13.572	13.572	0.000	12.893	0.679	13.572	0.0%
W15	0.000	34.796	34.796	0.000	33.056	1.740	34.796	0.0%
W16	0.000	39.019	39.019	0.000	37.068	1.951	39.019	0.0%
W17	0.000	84.250	84.250	0.000	80.038	4.213	84.250	0.0%
Total Phosphorus								
W01	0.214	1.921	2.135	0.214	0.821	0.043	1.078	49.5%
W02	2.676	1.418	4.094	2.676	0.607	0.032	3.315	19.0%
W03	0.000	16.736	16.736	0.000	7.155	0.377	7.532	55.0%
W04	0.000	1.170	1.170	0.000	0.501	0.026	0.527	55.0%
W06	6.493	2.203	8.696	6.493	0.523	0.028	7.044	19.0%
W07	0.105	1.890	1.995	0.105	0.808	0.043	0.955	52.1%
W08	0.084	59.994	60.078	0.084	15.958	0.840	16.882	71.9%
W09	0.046	15.519	15.565	0.046	6.635	0.349	7.030	54.8%
W10	0.000	4.907	4.907	0.000	2.098	0.110	2.208	55.0%
W11	0.000	5.474	5.474	0.000	5.200	0.274	5.474	0.0%
W12	0.011	4.122	4.133	0.011	3.916	0.206	4.133	0.0%
W13	0.000	1.074	1.074	0.000	1.020	0.054	1.074	0.0%
W14	0.000	0.637	0.637	0.000	0.605	0.032	0.637	0.0%
W15	0.000	0.494	0.494	0.000	0.469	0.025	0.494	0.0%
W16	0.000	0.831	0.831	0.000	0.789	0.042	0.831	0.0%
W17	0.000	2.152	2.152	0.000	2.044	0.108	2.152	0.0%

Table 4-8. WLA summary for White Clay Creek Watershed

Subbasin	NPDES		Baseline Point Source Loads				WLA				Percent Reduction	
		Flow mgd	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN mg/L	TP mg/L	TN kg/day	TP kg/day	TN	TP
W01	PA0053783	0.0200	10.00	2.00	0.757	0.151	10.00	2.00	0.757	0.151	0.0%	0.0%
W02	PA0024066	0.2500	11.62	2.00	10.998	1.893	11.62	2.00	10.998	1.893	0.0%	0.0%
W06	PA0040436	0.0090	20.00	2.00	0.681	0.068	20.00	2.00	0.681	0.068	0.0%	0.0%
W06	PA0025488	0.3000	50.00	4.00	56.788	4.543	50.00	4.00	56.788	4.543	0.0%	0.0%
W07	PA0056898	0.0650	32.55	0.30	8.010	0.074	32.55	0.30	8.010	0.074	0.0%	0.0%
W09	PA0052451	0.0012	24.20	10.00	0.110	0.045	24.20	10.00	0.110	0.045	0.0%	0.0%
W12	DE0000191	0.0300	0.24	0.10	0.027	0.011	0.24	0.10	0.027	0.011	0.0%	0.0%

4.5.6 CSO Allocations

The City of Wilmington has 38 combined sewer overflows (CSOs) that discharge within the Christina River Basin study area. A summary of the baseline and allocated annual average nitrogen and phosphorus for CSOs grouped by EFDC model grid cell is provided in Appendix E, Table E-5. After applying the TMDL allocations listed in Tables 4-1 to 4-8, the water quality model indicated that the TP target of 0.2 mg/L was protected in lower Brandywine Creek and lower Christina River where the CSOs discharge. However, the model indicated that the TN target of 3.0 mg/L and the water quality standards for DO were not protected; therefore, the CSO loads were reduced to meet these endpoints. The combined reduction of nutrients from the watershed loads and the CSO loads resulted in achievement of the TN target and protection of the DO water quality standards in lower Brandywine Creek and lower Christina River. The baseline and allocated annual average loads for CSO discharges from the City of Wilmington are shown in Table 4-9.

Please note that the TMDL CSO load reductions shown in Appendix E, Table E-5, are one scenario of load reductions, which, together with other sources' reductions, result in achieving instream water quality criteria throughout the length of the impaired waterbody. It should be noted that other scenarios are possible. In the future DNREC may allow an alternate CSO load reduction scenario, which also demonstrates that water quality standards are met throughout the length of the impaired waterbody.

Table 4-9. Annual average baseline and WLA nitrogen and phosphorus loads for CSO discharges

Location	CSO ID numbers	Baseline (kg/yr)	WLA (kg/yr)	Reduction
Total Nitrogen				
Little Mill Creek (C05)	27, 28, 29	951.2	225.6	76.3%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	2164.8	595.3	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	4176.7	1499.1	64.1%
Total CSO load	-	7292.7	2319.9	68.2%
Total Phosphorus				
Little Mill Creek (C05)	27, 28, 29	161.0	38.0	76.4%
Christina River (C09)	5, 6, 7, 9a, 9c, 10, 11, 12, 13, 14, 15, 16, 17, 30	366.1	100.7	72.5%
Brandywine Cr. (B34)	3, 4a, 4b, 4c, 4d, 4e, 4f, 18, 19, 20, 21a, 21b, 21c, 22b, 22c, 23, 24, 25, 26, RR	717.6	266.5	62.9%
Total CSO load	-	1244.7	405.2	67.4%

4.6 Consideration of Critical Conditions

Federal Regulations (40 CFR 130.7(c)(1)) require TMDLs to consider critical conditions for streamflow, loading, and water quality parameters. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable. Critical conditions include combinations of environmental factors that result in attaining and maintaining the water quality criteria and have an acceptably low frequency of occurrence (USEPA, 2001). The nutrient and low DO TMDLs for Christina River Basin adequately address critical conditions for flow and loading through analysis of a 4-year hydrologic simulation that includes typical low and high flow extremes in the basin.

4.7 Consideration of Seasonal Variation

The critical conditions for nutrient impairments of aquatic life habitat cannot be defined with a fixed flow rate. A long-term continuous simulation is the one way to determine when the nutrient concentrations are above the target endpoints. Therefore, the models were run for a four-year period (October 1, 1994 to October 1, 1998). This period is characterized by both extreme low flows during the summers of 1995 and 1997 as well as high-flow events during storms. This simulation period covered the range of typical critical hydrological conditions expected in the Christina River Basin.